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Role of MRI in evaluation of spinal trauma, its correlation with clinical profile and neurological outcome using ASIA impairment scale.

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Abstract

Diagnostic imaging, particularly Magnetic Resonance Imaging (MRI), plays crucial role in evaluating and detecting spinal trauma. Subtle bone marrow, soft tissue and spinal cord abnormalities, which may not be apparent on other imaging modalities, can be readily detected on MRI. Early detection often leads to prompt and accurate diagnosis, expeditious management, avoidance of unnecessary procedures. 65 patients of acute spinal trauma who underwent MRI of spine in the department of radiodiagnosis, Acharya Vinoba Bhave Rural Hospital, Sawangi, Wardha were included in the study. Detailed neurological examination of the patient was done during the scan. Detailed neurological examination of the patient was also done during his or her discharge from the Hospital. Clinical assessment was done at the time of admission and discharge using ASIA impairment scale. MRI findings were subsequently compared were clinical profile and neurological outcome. The strength of association between extent of spinal cord injury and outcome were described using Odd's ratio. Chi square test of significance ($p<0.005$) was used to assess the association between MR findings and clinical outcome.

Keywords: ASIA impairment scale, MRI, spinal trauma, cord injury.

Introduction

Diagnostic imaging, particularly Magnetic Resonance Imaging (MRI), plays crucial role in evaluating and detecting spinal trauma. Subtle bone marrow, soft tissue and spinal cord abnormalities, which may not be apparent on other imaging modalities, can be readily detected on MRI. Early detection often leads to prompt and accurate diagnosis, expeditious management, avoidance of unnecessary procedures.

Many advantages of MRI such as, higher contrast resolution, absence of bony artefacts, multiplanar capability and choice of various pulse sequences make possible to diagnose spinal trauma more accurately. Adequate information about neural and extra neural injuries requiring surgical interventions, for example, significant disc herniations and epidural hematomas, can be obtained in case of spinal cord oedema, contusion, haemorrhagic and ischemia, MRI findings may serve as prognostic indicators.

Most of the diagnostic information in spinal trauma is derived from the sagittal images. Axial images serve as a supplement[1]. Sagittal T1- Weighted images offer an excellent anatomic overview. Disc herniations, epidural fluid collections, subluxation, vertebral body fractures, cord swelling and cord compression are also visualised[2]. Sagittal T2- Weighted images depict most of the soft tissue abnormalities including spinal cord oedema and haemorrhage, ligamentous injury, disc herniations and epidural fluid collections[3]. Axial and sagittal GE images aid in the identification of the acute spinal cord haemorrhage, disc herniations and fractures. The depiction of parenchymal SCI on MRI not only correlated well with the degree of neurologic deficit, but it also bears significant implications in regard to prognosis and potential for neurologic recovery[4-13].

As MRI is an excellent diagnostic modality for evaluation of spinal trauma, it is possible to suggest that the MRI findings correlated directly with the degree of deficit according to ASIA impairment scale. The purpose of this study is to evaluate this correlation.

Materials and Methods

Source of data: Cases of acute spinal trauma who underwent MRI of spine in the department of radiodiagnosis, Acharya Vinoba Bhave Rural Hospital, Sawangi, Wardha were included in the study. Detailed neurological examination of the patient was done during the scan. Detailed neurological examination of the patient was also done during his or her discharge from the Hospital.

Type of study: Hospital based prospective study.

Study Period: June 2017 to August 2019

Sample size: 65 patients with spinal trauma irrespective of age, sex referred to Acharya Vinoba Bhave Rural Hospital, Sawangi (Meghe) were included. After giving informed consent and ethical clearance, patients had MR imaging done

Equipment: *GE* MRI 1.5 tesla with phase array coil was used for acquisition of images in all patients.

Method of collection of data: MR imaging of spine was performed in the axial and saggital planes using a combination of pulse sequences. The study was performed with patient in supine position with quiet breathing obtaining saggital T2 and T1-weighted fast spin echo images, STIR, coronal STIR and axial T2 and T1-weighted fast spin echo images for proper evaluation of cord hemorrhage.

Saggital images were 5.0mm thick with a 0.5m slice gap. The field of view (FOV) of the area of interest is adequate at 24 cm in cervical spine and at 32 cm in lumbosacral spine. In the dorso-lumbar spine, a large FOV was needed (34/36 cm) for accurate labelling of the involved levels.

T2-weighted information was obtained using a single FSE acquisition using a split echo train, resulting in an intermediate T2-weighted sequences. For the short TE image, an echo train of three with two excitations was used, whereas for the long TE image an echo train of 15-30 with single excitation was used. For each sequence, 256-448 steps were followed in both the frequency and phase axes. Fat suppression was employed on the long TR sequences to improve visualisation of edema in the posterior ligamentous complexes (STIR- Short Tau Inversion Recovery). Axial images were obtained using FSE or gradient echo (GRE) pulse sequences. Technical parameters included 16 degree flip angle, minimum TR/TE, 224 x 320 matrix and two excitations in T1WI and one excitation in T2WI. The TE used was less than 15 ms in T1WI and upto 100 ms in T2WI in order to minimize

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unwanted susceptibility effects that might exaggerate bony stenosis.

The following findings were identified after assessing the MR images and considered for the study:

1. Cord hemorrhage
2. Cord edema >3cm in length.
3. Cord edema <3cm in length.
4. Fracture of vertebral body, posterior elements.
5. Normal cord

Clinical assessment of spinal cord injury

A standardized physical examination as endorsed by the International standards for neurological and functional classification of spinal cord injury patients, also commonly called the American Spinal Injury Association (ASIA) guidelines was performed. A detailed motor and sensory examination of the patient was done and graded according to American Spinal Injury Association scale which is as follows:

A-	Complete:	No motor or sensory function is preserved in the sacral segments S4–S5.
B-	Incomplete:	Sensory function preserved but not motor function is preserved below the neurological level and includes the sacral segments S4–S5.
C-	Incomplete:	Motor function is preserved below the neurological level, and more than half of key muscles below the neurological level have a muscle grade less than 3.
D-	Incomplete:	Motor function is preserved below the neurological level, and at least half of key muscles below the neurological level have a muscle grade of 3 or more.
E-	Normal:	Motor and sensory function is normal.

Data analysis: The strength of association between extent of spinal cord injury and outcome were described using Odd's ratio. Chi square test of significance ($p<0.005$) was used to assess the association between MR findings and clinical outcome.

Inclusion criteria: All the patients of acute spinal trauma undergoing MR imaging formed the study group.

Exclusion criteria

1. Post operative patients of spinal trauma undergoing MRI scan of spine.
2. Uncooperative patients.
3. Patients with metallic implants, Patients with pacemaker / cochlear implant in-situ, Patients with claustrophobia/ any other psychiatric abnormality.

Observation and Results

In this study 65 cases with spinal trauma were observed. Of these 48 (73.84%) were males and 17 (26.15%) were females.

Table 1: Cause of injury in the patients

Cause	Number	Percentage
Road Traffic Accident	20	30.76%
Fall from height	29	44.61%
Assault	8	12.30%
Blunt trauma	8	12.30%

The most common cause of injury was fall from height which was the cause in 29 patients (44.61%), followed by road traffic accidents in 20 patients (30.76%). Other causes such as assault and blunt trauma were present in 8 patients each (12.30%).

Table 2: Site of injury in the patients

Site	Number	Percentage
Cervical spine	26	40%
Dorsolumbar spine	14	21.53%
Dorsal spine	12	18.46%
Lumbar spine	11	16.92%
Sacral spine	2	3.07%

Most commonly affected region by the spinal trauma was cervical spine, comprising of 26 patients (40%). Dorsolumbar and dorsal spine were also commonly affected, comprising of 14 (21.53%) and 12 (18.46%) patients respectively. Lumbar spine involvement was seen in 11 patients (16.92%) and sacral spine was involved in only 2 patients (3.07%).

Table 3: Cord findings in MRI in spinal trauma

Cord Findings	No. of patients	Percent	95% confidence limit
Hemorrhage	5	7.69	2.54%-17.05%
Cord edema (<3cm)	20	30.76	19.91%-43.45%
Cord edema (>3cm)	11	16.92	12.31%-33.49%
No abnormality	29	44.61	28.04%-52.90%
Total	65	100	

MRI examination revealed the cord abnormalities in 36 out of 65 patients, i.e. in 55.38% of patients. Rest 29

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patients (44.61%) had no findings in MRI. Cord edema more than 3 cm was there in 11 out of 65 patients (16.92%). Cord edema less than 3 cm was there in 20 out of 65 patients (30.76%) while 5 patients (7.69%) showed hemorrhagic focus within the cord in MRI.

Table 4: Comparison of MRI findings with clinical profile of the patients

AIS	No. of patients at admission			No. of patients at discharge		
	No of patients	percentage	95% confidence limit	No of patients	percentage	95% confidence limit
A	14	21.54	12.31%-33.49%	12	18.46	9.92%-30.03%
B	5	7.69	2.54%-17.05%	4	6.15	1.70%-15.01%
C	8	12.31	5.47%-22.82%	6	9.21	3.46%-19.02%
D	14	21.54	12.31%-33.49%	11	16.92	8.76%-28.27%
E	24	36.92	25.28%-49.80%	32	49.23	36.60%-61.93%
Total	65	100.00		65	100.00	

In our study we found out that initial paralysis was AIS A in 14 patients (21.53%), B in 5 patients (7.69%), C in 8 patients (12.30%), D in 14 patients (21.53%) and E in 24 patients (36.92%). At the time of discharge paralysis was AIS A in 12 patients (18.46%), B in 4 patients (6.15%), C in 6 patients (9.23%), D in 11 patients (16.92%) and E in 32 patients (49.23%).

Table5: AIS at admission and discharge in patients with cord hemorrhage

AIS	No. of patients at admission		No. of patients at discharge	
	No of patients	Percentage	No of patients	Percentage
A	5	100.00	4	80.00
B	0	0.00	1	20.00
C	0	0.00	0	0.00
D	0	0.00	0	0.00
E	0	0.00	0	0.00
Total	5	100.00	5	100.00

In patients with focus of cord hemorrhage all the 5 patients were graded initially as AIS A and out of them only 1 patient (20%) improved to AIS B. 80% of them showed no improvement.

Table 6: AIS at admission and discharge in patients with cord edema more than 3 cm

AIS	No. of patients at admission		No. of patients at discharge	
	No of patients	Percentage	No of patients	Percentage
A	7	63.63	6	54.54
B	2	18.18	1	9.09
C	1	9.09	2	18.18
D	1	9.09	2	18.18
E	0	0.00	0	0.00
Total	11	100.00	11	100.00

In 11 patients with cord edema more than 3 cm, 7 patients (63.63%) were initially graded as AIS A, 2 patients (18.18%) were graded AIS B, 1 patient each (9.09%) was graded AIS C and D. 1 out of 7 patients (14.28%) with AIS A improved to AIS C and 1 out of 2 patients (50%) with AIS B improved to AIS D. Patients with AIS C and D showed no improvement.

Table 7: AIS at admission and discharge in patients with cord edema less than 3 cm

AIS	No. of patients at admission		No. of patients at discharge	
	No of patients	Percentage	No of patients	Percentage
A	2	10.00	2	10.00
B	2	10.00	1	5.00
C	5	25.00	3	15.00
D	9	45.00	9	45.00
E	2	10.00	5	25.00
Total	20	100.00	20	100.00

In 20 patients with focus of cord edema less than 3 cm, 2 patients (10%) were initially graded as AIS A, 2 patients (10%) were graded as AIS B, 5 patients (25%) were graded as AIS C, 9 patients (45%) were graded as AIS D and 2 patients (10%) were graded as AIS E. 1 out of 2 patients (50%) with AIS B and 2 out of 5 patients (40%) with AIS C improved to AIS D while 3 out of 9 patients (33.33%) with AIS D improved to AIS E. Patients with AIS A showed no improvement.

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Table 8: AIS at admission and discharge in patients with no cord findings

AIS	No. of patients at admission		No. of patients at discharge	
	No of patients	Percentage	No of patients	Percentage
A	0	0.00	0	0.00
B	1	3.44	1	3.44
C	2	6.89	1	3.44
D	4	13.79	0	0.00
E	22	75.86	27	93.10
Total	29	100.00	29	100.00

In 29 patients with no cord findings 22 patients had no clinical neurological deficit and hence as AIS E (75.86%). 1 patient (3.44%) was initially graded as AIS B. 2 patients (6.89%) were initially graded AIS C and 4 patients (13.79%) were initially graded as AIS D.

The patient with AIS B showed no improvement. 1 out of 2 patients (50%) with AIS C showed no improvement while the other patient (50%) showed improvement to AIS E. All 4 patients with AIS D (100%) showed improvement to AIS E.

Table 9: Outcome in patients of spinal trauma according to ASIA impairment scale

AIS	Improvement		Non-improvement		Total	
	No of patients	percentage	No of patients	percentage	No of patients	percentage
A	2	14.29	12	44.44	14	34.15
B	2	14.29	3	11.11	5	12.20
C	3	21.43	5	18.52	8	19.51
D	7	50.00	7	50.00	14	34.15
Total	14	100.00	27	100.00	41	100.00

Out of 14 patients with initial AIS A, only 2 patients (14.28%) showed improvement while out of 5 patients with initial AIS B, 2 patients (40%) showed improvement. In 8 patients having initial AIS C, 3 patients (37.5%) showed improvement and in 14 patients with initial AIS D, 7 patients (50%) showed improvement.

Table 10: Various cord finding and their effect on outcome (Multi variate analysis)

Outcome	Odds ratio (95% confidence limit)	p-value
Cord hemorrhage	6.73 (1.17-38.63)	0.032
Cord edema less than 3 cm	0.35 (0.44-1.87)	0.149
Cord edema more than 3 cm	0.41 (0.59-31.5)	0.178

Discussion

This prospective study was performed in 65 patients of spinal trauma referred for an MRI examination.

The results of the study have shown that the MRI is an excellent diagnostic modality for the evaluation of patients of spinal trauma. It accurately defines the extent of spinal cord injury and the imaging findings correlate with the clinical neurological examination findings according to the ASIA impairment scale.

Out of 65 patients, 48 were males and 17 were females. The age group most commonly affected were those in the age group of 21-40 years (55.38%). This was in concordance with Shih P. et al[14] which showed that the spinal trauma was more common in men and the age group of 25-40 years.

The most common cause of injury was fall from height which was the cause in 29 patients (44.61%), followed by road traffic accidents in 20 patients (30.76%). Other causes such as assault and blunt trauma were present in 8 patients each (12.30%). This was in accordance to a study by Gupta N et al, where in fall from heights was observed in 25% of the cases[15]. In another study by Rao MUM et al, 50% of the patients suffered spinal injuries due to fall from heights and 17.4% was due to road traffic accidents, which corroborated this study[16]. In a study by Nagvekar RA et al, 62% was due to fall from heights and 37% due to road accidents[17].

Most commonly affected region by the spinal trauma was cervical spine, comprising of 26 patients (40%). Dorsolumbar and dorsal spine were also commonly affected, comprising of 14 (21.53%) and 12 (18.46%) patients respectively. Lumbar spine involvement was seen in 11 patients (16.92%) and sacral spine was

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involved in only 2 patients (3.07%). Similar results were observed by Rahman et al[18], Nagvekar RA et al[17] and Lenehan B[19] in their studies.

Osseous and ligamentous injuries

Out of total 65 patients, 34 patients had osseous injuries (52.30%). Out of 34 patients with the osseous injuries, vertebral fracture was observed in 22 (64.70%) of the patients, posterior elements fracture was observed in 10 (29.41%) patients and dislocation was observed in 11 (32.35%) of the patients. Intervertebral injuries were observed in 8 (23.52%) of the patients. Similar results were observed by Nagvekar RA et al[17] in their study. While in the study done by Johny prasad bollipo et al[20] vertebral fracture was observed in 47.4% of the patients, posterior elements fracture was observed in 6.4% patients and dislocation was observed in 26.9% of the patients. Intervertebral injuries were observed in 28.2% of the patients.

Out of total 65 patients, 30 patients (46.15%) had ligamentous disruption. Among the ligament disruption, anterior longitudinal and posterior longitudinal injuries were observed in 18 (60%) and 20 (66.66%) of the patients respectively. Ligamentum flava and interspinous ligament injury was seen in 12 patients (40%) while as paraspinal soft tissue changes were seen in 16 (53.33%) of the patients. In the study done by Johny prasad bollipo et al[20] anterior longitudinal and posterior longitudinal injuries were observed in 38.5% and 43.6% of the patients respectively. Paraspinal soft tissue changes were seen in 24.4% of the patients.

Abnormal cord findings in MRI in spinal trauma

MRI showed cord abnormalities were present in 36 out of 65 patients, i.e. in 55.38%. No abnormalities were found in 29 patients, i.e. in 44.61%. This was in concordance with Umesh C. Parashari et al[21] which showed spinal cord abnormalities in 55%.

Focus of cord hemorrhage was present in 5 out of 65 patients, i.e., 7.69% of patients with 95% confidence limit of 2.54%-17.05%. Cord edema/non-hemorrhagic contusion involving more than 3 cm was present in 11 out of 65 patients, i.e., 16.92% of patients with 95% confidence limit of 12.31%-33.49%. Cord edema/non-hemorrhagic contusion involving less than 3 cm was present in 20 out of 65 patients, i.e., 30.76% of patients with 95% confidence limit of 19.91%-43.45%. So cord edema/contusion involving less than 3 cm of the cord was most common finding in our study.

Comparison of MRI findings with clinical profile of the patients

In our study we found out that initial paralysis was grade AIS A in 14 patients (21.53%), B in 5 patients (7.69%), C in 8 patients (12.30%), D in 14 patients (21.53%) and E in 24 patients (36.92%).

In patients with focus of cord hemorrhage all the 5 patients were graded initially as AIS A and out of them only 1 patient (20%) improved to AIS B. 80% of them showed no improvement. It may suggest that the patients with cord hemorrhage come with complete paralysis and also initial high grade AIS did not show significant improvement.

In 11 patients with cord edema more than 3 cm, 7 patients (63.63%) were initially graded as AIS A, 2 patients (18.18%) were graded AIS B, 1 patient each (9.09%) was graded AIS C and D. 1 out of 7 patients (14.28%) with AIS A improved to AIS C and 1 out of 2 patients (50%) with AIS B improved to AIS D. Patients with AIS C and D showed no improvement.

In 20 patients with focus of cord edema less than 3 cm, 2 patients (10%) were initially graded as AIS A, 2 patients (10%) were graded as AIS B, 5 patients (25%)

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were graded as AIS C, 9 patients (45%) were graded as AIS D and 2 patients (10%) were graded as AIS E. 1 out of 2 patients (50%) with AIS B and 2 out of 5 patients (40%) with AIS C improved to AIS D while 3 out of 9 patients (33.33%) with AIS D improved to AIS E. Patients with AIS A showed no improvement.

It may be suggested that the patients with cord hemorrhage and patients with cord edema more than 3 cm come with almost complete paralysis and also initial high grade AIS will not show significant improvement.

In 29 patients with no cord findings, 22 patients had no clinical deficit and hence graded as AIS E (75.86%). 1 patient (3.44%) was initially graded as AIS B. 2 patients (6.89%) were initially graded AIS C and 4 patients (13.79%) were initially graded as AIS D. The patient with AIS B showed no improvement. 1 out of 2 patients (50%) with AIS C showed no improvement while the other patient (50%) showed improvement to AIS E. All 4 patients with AIS D (100%) showed improvement to AIS E.

This suggests that there was some amount of neurological deficit even with the cord being normal. This may be attributed to presence of non-cord abnormalities like cord compression, fractured segments, soft tissue hematoma which indirectly effect the cord like in SCIWORA.

Correlation of MRI findings with clinical profile of patients and neurological outcome

In our study 14 out of 65 patients (21%) showed improvement and 29 patients (45%) showed no improvement. 22 patients (34%) had no neurological deficits on admission.

Out of 5 patients with cord hemorrhage, only 1 patient (20%) showed improvement and 4 patients (80%) showed no improvement.

Out of 11 patients with cord edema more than 3 cm, only 2 patients (18%) showed improvement and 9 patients (82%) showed no improvement.

Out of 20 patients with cord edema less than 3 cm, 6 patients (30%) showed improvement and 14 patients (70%) showed no improvement.

Out of 7 patients with neurological deficit but no cord abnormalities, 5 patients (71%) showed improvement and 2 patients (29%) showed no improvement.

This suggests that patients with cord hemorrhage have less chance of recovery.

Out of 14 patients with initial AIS A, only 2 patients (14.28%) showed improvement while out of 5 patients with initial AIS B, 2 patients (40%) showed improvement. In 8 patients having initial AIS C, 3 patients (37.5%) showed improvement and in 14 patients with initial AIS D, 7 patients (50%) showed improvement.

This suggests that chances of improvement are less in patients with initial high grade AIS.

In patients with presence of sizable focus of cord hemorrhage, 1 patient (20%) showed improvement in sensory scores. While considering edema as a risk factor sensory improvement was noted in 2 out of 11 patients (18%) with cord edema more than 3 cm and improvement was there in 6 out of 20 patients (30%) with cord edema less than 3 cm.

Odds ratio is 2.75 (95% confidence limits 0.95-36) and the Fischer's exact P value is 0.0427 ($P<0.05$) which is significant. It indicates that in patients with cord edema involving >3 cm of cord, chances of sensory improvement was 2.75 times lesser than in patients with cord edema involving <3 cm of cord.

Multivariate analysis was done to see the the effect of various risk factors studied on the outcome of trauma patients. It shows that over and above all the risk

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factors only focus of cord hemorrhage was significantly associated with poor prognosis (Odds ratio-6.73, 95% confidence limits 1.2-38.6, P=0.032)

In a similar study, Boldin et al[22] showed the effect of hemorrhage and length of hematoma on neurological impairment. They showed that patients with hemorrhage were more likely to have complete spinal cord injury at the time of follow up (odds ratio=2.33, 95% confidence limits 1.42-3.82). Similar to our study they also showed that presence of large hemorrhage was associated with complete spinal cord injury and showed poor prognosis.

Similar results were also shown by Andreoli C[23.] They demonstrated that patients with initial hemorrhage had poor prognosis while those with edema had better prognosis. Flanders et al[5] showed that patients without spinal cord hemorrhage had significant improvement in self-care and mobility scores compared to patients with hemorrhage. Their study revealed that rostral limit of edema positively correlated with admission and discharge self-care scores. Poor prognostic factors were hemorrhage, long length of cord edema and high cervical location.

Selden NR[24] also showed similar results- presence of long length of intra-axial hematoma and cord edema, each associated with poor neurological outcome.

In their contrary, randomized clinical trials by Shepard MJ[25] showed that MRI provides diagnostic information on degree of damage to bone and soft tissues but does not add much to diagnosis of neurological function, although they showed that presence of hemorrhage is associated with worse prognosis but did not provide any prognostic information. AE Flanders et al[5] also showed similar result as our study. Patients with hemorrhage had lower motor scores with poor recovery (P<0.001). They performed multiple regression analysis and stated that MR information on hemorrhage and edema increases the ability to predict clinical outcome by 16.33% over that initial clinical score alone.

Philippe Demaerel[26] showed the utility of MRI in determining the management of spinal trauma. They showed that MR is also indicated for the evaluation of patients with late complications and sequelae following spinal trauma. Andreoli C.[23] showed the strong correlation between MRI appearance of traumatic spinal cord injuries in acute phase and long-term recovery of motor and sensory functions. MRI is particularly useful in unconscious patients who cannot undergo motor and sensory neurological evaluation.

Saifuddin[27] also established that MRI is a vital imaging technique. Seiden NR showed that emergency MRI after spinal cord injury provides accurate prognostic information regarding neurological function and aids in diagnosis and treatment of cases of persistent cord compression after vertebral alignment. Slucky AV[28] et al showed that MRI of acute spinal injury provides excellent visualization of neurological and soft tissue structures in non-invasive format. Slucky AV[28] et al also showed the correlation of MRI findings with experimental and clinical SCI with a relative predictive value to SCI pattern on MR images indicative of long term neurological outcome.

Conclusion

MRI is the imaging modality of choice in the evaluation of cord abnormality in spinal trauma cases. MRI is not only a diagnostic tool in spinal trauma but also a prognostic predictor. It is possible to predict the neurological outcome of the patients with different cord abnormalities. Patients with cord hemorrhage and significant cord edema not only present with complete to near complete neurological deficit but also show less or no improvement in follow up. Patients with small

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cord edema have comparatively better prognosis. Other non-cord findings like osseous injuries, ligamentous disruption and soft tissue abnormalities and their effect on the cord can also be evaluated on MRI study. In spite of its cost, MRI has been readily accepted by both patients and referring clinicians.

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